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An Evaluation of Acoustic Analysis Training in the Aviation Antisubmarine Warfare Operator (AW) Class "A" School

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The Interactive Multisensor Analysis Training (IMAT) System was developed to address post Cold War ASW training requirements. It is designed to teach the complex conceptual knowledge and cognitive and procedural skills required to reason about the interrelationships among the operating modes of target submarines, the environmental variables that affect sound transmission, and the sensor systems used for detection and tracking. This effort evaluated the application of the IMAT system in the Aviation Antisubmarine Warfare Operator (AW) Class "A" School. The results showed that (1) research on cognition and instruction and technological advances in scientific visualization can be integrated and applied in real world training to produce substantial gains in performance and student motivation, (2) the IMAT system has achieved its intended design goals by effectively teaching complex knowledge and cognitive skills, and (3) the IMAT system emphasis on inclusion of required instructional components contributed significantly to the observed performance improvements.

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Foreword

The evaluation of the Acoustic Analysis Lessons of the Aviation Antisubmarine Warfare Operator (AW) Class "A" School were conducted under the 6.3 Manpower, Personnel, and Training Advanced Technical Development Program Element 0603707N (Work Unit 063707N.L2335.IM001). The goal of this study was to evaluate the effectiveness of the Interactive Multisensor Analysis Training (IMAT) System in an operational training environment.

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Summary

Problem and Background

The challenges facing Antisubmarine Warfare (ASW) training in the late 1990s are greater than at any time since the early days of World War II. Conditions since the end of the Cold War, and those expected throughout the next decade, impose additional complexity on maintaining U.S. ASW superiority. Russian nuclear submarine technology continues to improve and advanced submarines continue to be built and delivered to their fleet. Concurrently, the proliferation of improved diesel submarine technology to many Third World nations requires that our ASW forces also be capable of conducting operations in the vastly different littoral regions.

The training challenge is two-fold: (1) retaining the capability to detect and prosecute nuclear submarines, and (2) expanding our current capability against diesel submarines of the Third World. When coupled with dramatic reductions in ASW training resources, including at-sea training, this historic change compels the development of training for skills learned previously on the job and for skills required in new environments.

The Interactive Multisensor Analysis Training (IMAT) System was developed to address post Cold War ASW training requirements. Specifically, IMAT is designed to teach the complex conceptual knowledge and cognitive and procedural skills required to reason about the interrelationships among the operating modes of target submarines, the environmental variables that affect sound transmission, and the sensor systems used for detection and localization. In addition, IMAT provides extensive training on submarine acoustics and interpretation of sensor system data. The IMAT approach to training is based on recent advances in cognitive psychology and instructional technology. It combines cognitive analytic and curriculum design technology with advanced computer-based graphics (scientific visualization) and programming technology to present state-of-the-art training.

Objective

The objective of this effort is to evaluate the application of the IMAT system in the acoustic analysis portion of the Aviation Systems Warfare Operator (AW) "A."

Method

The AW "A" Acoustic Analysis lessons were evaluated on (1) student performance on two types of end of unit test items (fact items and cognitive skill/acoustic analysis items), (2) student motivation, and (3) quality of instructional design. Fifty-three students, trained with the IMAT system, were compared with 22 students trained with the standard instruction used in the "A" school prior to the introduction of IMAT.

Results

IMAT students performed better than standard instruction students on both fact items and cognitive skill items. This finding shows that the combination of strategies incorporated in the IMAT system provides an effective environment for learning complex knowledge and skills. Further, IMAT students performed better on cognitive skill items relative to fact items than the standard instruction students. This result is exactly what IMAT was designed to accomplish and directly addresses the post Cold War training requirements for sensor operators.

The instructional design analysis found that in the IMAT lessons all required instructional components were present, while components were present to a lesser degree for the standard instruction lessons.

The motivation analysis showed that IMAT instruction compared favorably with similar computer based instruction and was generally more motivating than standard classroom instruction.

Conclusions

Several conclusions can be drawn from this study. First, the IMAT approach to classroom training, which is based on computer-generated dynamic displays (scientific visualization) and instructional design and delivery strategies designed to enhance cognition, produced substantial gains in performance. This is especially true for the explicit IMAT goal of teaching complex knowledge and cognitive skills. Second, the IMAT system emphasis on adhering to the principles of high quality instructional design was supported in the instructional design analyses. The differences in design quality between the standard instruction and IMAT groups undoubtedly contributed to the observed performance differences. Overall, the results show that IMAT is a highly effective training system that offers a viable solution for many of the training requirements and challenges faced in the post Cold War world.

Contents

Introduction

Problem and Background

The challenges facing Antisubmarine Warfare (ASW) training in the late 1990s are greater than at any time since the early days of World War II. During the Cold War, ASW mission requirements (and the training designed to support those requirements) were driven by the need to combat Soviet nuclear submarines in open ocean environments. The prevailing ASW strategy was designed to detect and prosecute enemy submarines at long ranges, and operations were most often conducted by single ASW units with minimal coordination with outside assets. The relatively benign deep ocean environment and nearly exclusive focus on the Soviet threat resulted in the development of effective and well practiced sensor and weapons tactics. ASW training mirrored that relatively narrow focus, and, combined with frequent real-world encounters, was quite effective in producing competent ASW sensor operators.

Conditions since the end of the Cold War, and those expected throughout the next decade, impose additional complexity on maintaining our ASW superiority. Russian nuclear submarine technology continues to improve and advanced submarines continue to be built and delivered to their fleet. Concurrently, the proliferation of improved diesel submarine technology to many Third World nations requires that our ASW forces also be capable of conducting operations in the vastly different littoral regions.

Littoral environments introduce added difficulty in optimally employing onboard sensors and weapons tactics. Coastal areas with shallow water, complex bathymetry and bottom topography, heavy shipping, and highly variable environmental conditions impose significant restrictions on traditional deep water tactics. The diesel submarine operating in home waters has the additional advantage of familiarity with environmental anomalies, slow speed operation, and support from own nation defense systems.

The training challenge has thus become two-fold; retaining the Cold War capability to detect and prosecute nuclear submarines while expanding our current capability against diesel submarines of the Third World. When coupled with dramatic reductions in ASW training resources, including at-sea training opportunities, this historic change compels the development of different approaches to training for sensor operators.

Traditional ASW Training for Sensor Operators

In the past the ASW training has been based on a balance between schoolhouse and operational training. To become journey level operators, students learned the basics in schoolhouse training and then received extensive on-the-job training through supervised practice by experienced fleet crews at-sea. The schoolhouse training focused on memorizing facts, procedures, and large databases of threat intelligence parameters. Students were not taught to think about and relate the underlying physics of threats, the environment and the sensor systems. This approach resulted in graduates who could answer specific factual questions based on memorized information and who could perform procedures but who had difficulty in applying knowledge and principles to solve

problems in operational situations. Great reliance was placed on a substantial amount of at-sea experience to transfer the knowledge and skill gained in formal training to operational competency.

Post Cold War ASW Training Requirements

All four ASW training communities (surface, subsurface, air, and surveillance) now agree that the combined change in threat, environment, and operating circumstances requires a new training approach.

Current fleet ASW practitioners receive little at-sea operational practice against non-cooperative submarines. As a result, an operator's ability to detect, classify, and track submarine targets will be directly related to the quality of initial training, and to how well those skills are maintained and increased throughout a career. To achieve this level of competence, the limited hours available for both schoolhouse and at-sea training must be used to provide both a solid conceptual understanding of the complex tasks that operators must perform as well as the opportunity to practice those tasks under varying real-world conditions.

Achieving these goals will require substantive changes the execution of schoolhouse and operational training. ASW training must see dramatic modifications to passive acoustic analysis training and substantial expansion of training in active sonar, radar, and electromagnetic sensor systems to enable operators to contribute effectively in a multi-sensor approach to submarine prosecution. Further, the complexity of the acoustic environment in the littoral regions requires a substantial increase in knowledge of the effects of ocean bathymetry on acoustic energy transmission and how that, in turn, affects sensor selection and placement. These training requirements can only be met through principle-based application of training technologies, which can provide conceptual knowledge and high fidelity experience to offset the lack of at-sea practice.

The Interactive Multisensor Analysis Training (IMAT) System

Overview

The Interactive Multisensor Analysis Training (IMAT) System was developed to address post Cold War ASW training requirements. Specifically, IMAT is a classroom based approach to training that is designed to teach the complex conceptual knowledge and cognitive and procedural skills required to reason about the interrelationships among the operating modes of target submarines, the environmental variables that affect sound transmission, and the sensor systems used for detection and localization. In addition, IMAT provides extensive training on submarine acoustics and interpretation of sensor system data.

The IMAT approach to training is based on recent advances in cognitive psychology and instructional technology such as scientific visualization (Baek & Layne, 1988, Bryson, 1994) and anchored instruction (Cognition & Technology Group at Vanderbilt, 1990). It combines cognitive analytic and instructional design technology with advanced

computer-based graphics and programming technology. The result is scientific visualization, a dynamic graphical interface integrated with state-of-the-art instructor and student guides which provides the traditional classroom instructor with a capability to effectively teach complex cognitive concepts and skills. In the past, achieving this capability has been hampered by limitations in cognitive task analysis, and particularly in cognitive models. In addition, limitations in computer capabilities have precluded the development of cause and effect representations of highly complex, multi-modal tasks that are required of expert practitioners. Recent developments in cognitively-based training design have demonstrated that models of physical phenomena can be integrated with high resolution graphics to demonstrate the interactive relationships (Bryson, 1994). The IMAT system extends that technology in the traditional classroom environment, with specific emphasis on cognitive design models that account the knowledge structure interrelationships of threat, environment, and system for operator training. IMAT provides cause and effect training for decision making with multiple system input, and allows visualization of interactive spatial relationships among operators, sensors and other platforms.

Specifically, for sensor operators IMAT apprentice training is presented in a mission context with a substantial emphasis on the interactive relationship among environmental factors, threat behavior, and sensor system capabilities and constraints. Because sensor operators at the apprentice level have limited backgrounds in submarine operations, the physics underlying energy transmission, and in operating complex sensor systems, establishing a good conceptual understanding of the complicated interactions that occur in the real world is the essential foundation for learning effective sensor operation. Students are taught to understand that the enemy submarine's mission will largely dictate its operating mode including course, speed, and depth of operation, and that the operating mode of the submarine defines its vulnerabilities to onboard acoustic and electromagnetic sensors. They are further taught how the relative complexity of the ocean environment will impact detection ranges, search rates, and contact duration. Students learn to reason through these interactions in a cause and effect learning process. Multi-dimensional interactions are displayed visually and the IMAT instruction provides qualitative explanations for the interactions that occur. IMAT presents demonstrations of varying outcomes based upon changes in the threat or environment to promote the development of the principle-based knowledge critical for adaptations to the variations presented in real world situations. Finally, tests of student proficiency for IMAT training include questions that require problem solving and understanding causal relationships in addition to the traditional fact recognition and procedural process items.

Research Background

The IMAT system integrates several areas of research on cognition and instruction, including, graphical techniques to promote visualization of invisible phenomena in science teaching, elaborated explanations, contextualized or anchored instruction, and instructional sequencing. The following sections briefly summarize portions of this work.

Scientific Visualization. Scientific visualization has traditionally been used by scientists to explore phenomena and to communicate with other scientists (Bryson, 1994). When used for presentations, researchers select data sets, transform them and then turn them over to specialized graphic artists to develop images and animation. However, the end products of this process have not been designed for laymen or students. IMAT aims to bring this technology into specialized technical training.

Research support for scientific visualization as a training strategy comes from the literature on instructional media. Both static and dynamic graphic displays have been shown to facilitate teaching of scientific concepts (Baek & Layne, 1988; Dwyer, 1972; Gropper, 1966; Lunsdaine, Sulzer, & Kopstein, 1961; Rieber, 1990; Rigney & Lutz, 1975; Park & Gittelman, 1992, Wetzel, Radtke, & Stern, 1994). Levie and Lentz (1982) in a meta-analysis of illustrated text studies concluded that learning and retention is facilitated by illustrations, if the illustrations are directly related to the text. Park and Gittelman (1992) found that subjects trained with dynamic graphics performed better on electronic troubleshooting problems then those trained with static displays. White (1984) used animated computer graphics to successfully teach the basic principles of Newtonian laws of motion and force. IMAT employs a computer based graphical interface to conceptual models of real world phenomena to deliver both static and dynamic graphics in a traditional classroom environment.

Elaborated Explanations. Providing students with elaborated explanations, analogies, etc. about how and why systems, events, and phenomena are structured and function has been shown to facilitate learning and retention. Research on learning skills and learning from text has shown that elaborated explanations enhance the students' mental models and increase retention (Mayer, 1989; Konoske & Ellis, 1991; Smith & Goodman, 1982). In a series of studies of learning from scientific text, Mayer (1989) found that providing students with a conceptual model increased learning, retention and transfer. The conceptual models in his instruction used both text and diagrams to highlight major objects and actions and the causal relations among them. That is, the models focused on how and why systems work. Smith and Goodman (1982) studied the effects of providing elaborated instructions on learning and performing a procedural assembly task and found that instructions containing functional information resulted in fewer errors. Swezey, Perez, and Allen (1991), in a study on transfer of electromechanical troubleshooting skill, found that some level of generic structure and functional knowledge is required for cross domain transfer. The IMAT system uses elaborated explanations throughout the instruction to (1) clarify complex relationships such as those among water temperature, pressure and depth, and salinity; (2) provide comprehensive feedback for practice exercise; and (3) describe graphically displayed examples.

Contextualized Instruction and Instructional Sequencing. Contextualized or job oriented instruction has been found to be more effective in learning, retention, and performance than topic oriented instruction (Semb & Ellis, 1994; Johnson, 1951; Goffard, Heimstra, Beecroft & Oppenshaw, 1960; Shoemaker, 1960; Steinemann, Harrigan, & VanMatre, 1967; Cognition & Technology Group at Vanderbilt, 1990;

Collins, Brown, & Newman, 1989). Further, within a job context, mental model development is facilitated by teaching students to reason about events and phenomena that involve several interrelated variables. Proper sequencing may play an important role in cognitive skill development. While early research on sequencing showed that with simplified or isolated tasks, different sequences of instructional events made little difference, more recent research and theory suggests that for complex tasks, sequencing strategies may have significant effects. For example, Reigeluth and Stein (1983) argues that beginning instruction with a condensed "holistic" overview of a task domain leads to better learning than more traditional sequences, which teach isolated topics first and integrate them later. More recently, extreme "constructivist" approaches to instruction (e.g. Duffy & Jonassen, 1991) argue that learners should "sink-or-swim" in a fully elaborated domain. Merrill, Li, & Jones (1990) also argue for a holistic approach to teaching complex domains, but include moderate structure and sequencing recommendations in their approach. Drawing from Reigeluth (1983), IMAT begins with a simplified overview of target, environment, and sensor system relationships in the context of the jobs and tasks performed by operators and tacticians. This context is revisited throughout IMAT to reinforce the reality that students are learning to do a job not memorize a list of topically related facts.

AW "A" School--Acoustic Analysis for Sensor Operators

In each of these areas, little experimental work has been done on the extent to which the findings are generalizable to instruction delivered using simulation- and graphical-interface-based training technologies. Furthermore, there are almost no larger efforts that evaluate the integration of these approaches into an overall strategy. The current effort tests the hypothesis that the IMAT system, which represents an integrated combination of these approaches, offers a potent learning environment for promoting acquisition of the complex knowledge and skills involved in sensor-system operation. Specifically, this report documents the implementation and evaluation of the IMAT system in the acoustic analysis portion of the AW "A" school in Pensacola. Although IMAT replaced the existing acoustic analysis lessons in the "A" curriculum, the basic classroom configuration and environment were not altered. However, the IMAT lessons represented a significant change from the existing instruction. The course length was increased from 212 to 230 hours and there were extensive changes in both the instructor and student guides, which were redesigned using IMAT criteria to provide both elaborated explanations and more contextualization. Furthermore, the IMAT graphical interface was used to provide the classroom instructor with both static and dynamic displays of important concepts and relationships including, low frequency analysis recording (LOFAR) displays, submarine operating characteristics, submarine equipment acoustic profiles, and target analysis and classification. All of these changes resulted in a course that emphasized learning cognitive skills and complex relationships instead of memorizing factual information, which was the focus of the existing unit.

Objective

The objective of this effort is to evaluate the application of the IMAT system in the AW "A" with respect to performance on factual and cognitive skill test items, student motivation, and instructional design.

Method

Design

The AW "A" IMAT application was evaluated on (1) student performance on two types of end of unit test items (fact items and cognitive skill items), (2) student motivation, and (3) quality of instructional design. Students trained with the IMAT system were compared with students trained with the conventional instruction used in the "A" school prior to the introduction of IMAT.

Subjects

The subjects were 22 students who had completed the AW "A" school acoustic analysis lessons prior to the introduction of the IMAT system (the standard instruction group), and 59 students who were taught the same unit with IMAT (the IMAT instruction group). Although ASVAB scores were not available because of privacy act considerations, the AW "A" school has ASVAB entry requirements that limit the range of student ability. Given random entry into the school, the student samples were considered to be equivalent in ability.

Instructional Materials

The lesson materials for both groups taught acoustical analysis and all groups were compared on identical end of unit test items. The major topics addressed were LOFAR display analysis, submarine drive train and drive train component analysis, analysis of mechanical and electrical machinery systems, and operational modes.

Standard Instruction

The number of learning objectives for the standard instruction is 48, which are taught in 212 hours with 99 class hours and 113 lab hours. The instruction is topic oriented rather than teaching the knowledge and skills in a job context. Neither the instructor guide nor the student guide provide many opportunities for practice in preparation for taking the unit test.

IMAT Instruction

The number of learning objectives for the IMAT instruction is 159, which are taught in 230 hours with 146 class hours and 82 lab hours. The instruction is presented in a job context with practice opportunities for each objective.

End of Unit Test

After completing the acoustic analysis lessons, students were given an end of unit test, which included items that could be used to compare IMAT and standard instruction. The test items were classified into one of two categories according to the type of information tested and the cognitive processing required to answer the question:

> **Remember fact**. The student must recall or recognize names, definitions, steps of procedures, formulas an terms in formulas, labels for graphical display, or technical terminology.
>
> **Cognitive skills**. The student must perform a sequence of steps, including making decisions and judgments, to solve a problem, calculate or determine a value or relationship, or evaluate a scenario.

The test items used for the evaluation were selected from a pool of test items developed for testing acoustic analysis knowledge and skills. All test items in the pool were reviewed by AW "A" course instructor personnel and by subject matter experts assigned to the IMAT project. Pool items that were rated beyond the scope of the instruction or inappropriate for "A" school training were eliminated. Test items selected for the evaluation were 4 fact items and 81 cognitive skill items. The 81 cognitive skill items were divided into two groups: (1) those explicitly taught by both the standard and IMAT instruction (common cognitive skill items) ($N = 62$) and (2) those topically related to the standard instruction but only specifically taught by the IMAT instruction (IMAT cognitive skill items) ($N = 19$). The three groups of items (facts, common cognitive skills, and IMAT cognitive skills) were analyzed separately.

Motivational Analyses

For the motivational analysis, a questionnaire based on the Attention-Relevance-Confidence-Satisfaction (ARCS) motivational assessment model originated by Keller (1992) was developed. The 34 item questionnaire, designed for application to technical training, was administered to all of the IMAT instruction students. Unfortunately, the motivation questionnaires for the standard instruction students were either not collected or were lost in transit and could not be analyzed. In a previous study (Ellis & Parchman, 1994), the ARCS questionnaire was administered to 76 AW "A" school students trained with the IMAT system. These data were used in the present evaluation for comparison. The ARCS questionnaire assess four motivational characteristics; attention, confidence, relevance, and satisfaction. The attention oriented questions assess how well the material captures the interest of the learners and stimulates their curiosity to learn. The relevance questions address how well the materials meet the needs and goals of the learner. The confidence questions ask the students to report on their beliefs and feelings about how well they will succeed and how much they can control their own success. The satisfaction questions concern students feelings of reward and accomplishment and their enjoyment of the materials. The four scales are scored from 1 to 5 with 1 indicating a statement about the course is "Not true" and a 5 indicating a statement is "Very true." A score of 3 indicates students believe a statement is "Moderately true."

Instructional Design Evaluation

The Course Evaluation System (CES) (Ellis, Knirk, Taylor, & McDonald, 1993) was used to compare the instructional design of the IMAT and standard instruction units. The CES assesses the consistency (match) among learning objectives, test items, and the instructional presentation, and the adequacy of the instructional presentation. Although the objectives for the IMAT and standard instruction groups were different, the test items were identical. Therefore, the CES was used to assess the consistency among the test items and the instructional presentations for each unit. The consistency assessments were then compared for the evaluation. The consistency assessment employed the same classification scheme for test items used for the end of unit test.

Results and Discussion

Test Analyses

A 2 Groups (standard instruction vs. IMAT instruction) by 3 Item Type (fact vs. common cognitive skill vs. IMAT cognitive skill) analysis of variance (ANOVA) was performed on percent correct for each type of item on the end of unit test. Table 1 presents the means for this analysis. The main effects group and the item type by group interaction were both significant ($p < .01$).

Table 1

Mean Percent Correct, Standard Deviations, and Effect Sizes for Fact, Common Cognitive Skill, and IMAT Cognitive Skill Test Items for IMAT and Standard Instruction Groups

	Facts $N = 4$	**Common Cognitive Skills** $N = 62$	**IMAT Cognitive Skills** $N = 19$	**Total** $N = 85$
STG standard instruction $N = 22$	76.1 SD = .20	72.1 SD = .11	49.0 SD = .13	67.1 SD = .10
IMAT instruction $N = 53$	81.1 SD = .16	86.7 SD = .08	82.5 SD = .10	85.5 SD = .08
Effect Sizes (Pooled SD)	.29	1.33	1.77	1.57

The finding that IMAT students performed better on all three types of test items supports the hypothesis that the combination of strategies incorporated in the IMAT system provides an effective environment for learning complex knowledge and skills. The most important result for the hypothesis is that IMAT instruction students performed

better on both types of cognitive skill items relative to fact items then the standard instruction students. That is, the significant groups by item type interaction shows that the IMAT system differentially increased learning and performance for the more complex types of items. This was especially true for the IMAT cognitive skill items, which reflect the addition of more complex objectives to the IMAT curriculum. This result is exactly what IMAT was designed to accomplish and directly addresses the post Cold War training requirements for sensor operators.

Instructional Design Analyses

The significant differences among the groups on all three types of test items can, in part, be explained by comparing the degree to which some of the fundamental instructional principles underlying the IMAT system were applied in each unit. The results of the CES analysis reveals these differences. For example, the total number of objectives for the IMAT lessons was 159 versus 48 for the standard instruction lessons. This resulted in part from the IMAT lessons being completely redesigned. The IMAT redesign reflects a thorough front-end analysis of the knowledge and skills that are required for proficiency and a concern for teaching the cognitive concepts and skills needed to perform acoustic analysis in a post Cold War world environment. These differences in number of objectives, depth of analysis, and training emphasis probably all worked to improve the performance of IMAT students.. However, the relatively small differences in unit length (230 hours for IMAT vs. 212 hours for the standard instruction) probably had little impact on the group differences. In fact, there was more laboratory time in the standard instruction (113 hours) then in the IMAT instruction (82 hours), and since laboratory time was used to practice many of the cognitive skills, this should have aided standard instruction students. Further, the common cognitive skill items were taught in both courses and used similar amounts of instructional time. (See Table 2 for percent of instructional components for each group.) The group difference on IMAT cognitive skills is only difference that can be attributed to more instructional time for IMAT students because those skills were not explicitly taught in the standard instruction.

The CES evaluation of the consistency among instructor and students guides and the test items also reveals differences among the two groups that may account for the performance differences. Table 2 shows percent of instructional components that are present in the instructor and student guides for each type of test item for each unit. For example, if there were 10 fact test items, each item would require a statement and an opportunity to practice remembering to be present somewhere in the instructor or student guides. If there were only five statements and three practice questions for the 10 fact items, the percentages in the Statement and Practice Remembering w/Feedback columns would be 50 percent and 30 percent, respectively. (Note that for fact items, the example and Practice Using components are not required.) In the IMAT lessons all required components are present, while components are present to a lesser degree for the standard instruction lessons. In the standard instruction the practice component for facts is missing 50 percent of the time. The absence of practice and other required instructional components for specific test items in the standard instruction may account for some of the performance differences between the groups.

Table 2

Percent of Each Required Presentation Component that is Present for Each Type of Test Item for the IMAT and Standard Instruction Units

	Required Presentation Components			
Test Item Type and Instructional Unit	**Statement**	**Practice Remembering w/Feedback**	**Examples**	**Practice Using w/Feedback**
Standard Instruction				
Fact (4 Items)	75.0	50.0	NA	NA
Common Cognitive Skill (62 Items)	95.4	NA	93.9	95.4
IMAT				
Fact (4 Items)	100.0	100.0	NA	NA
Common Cognitive Skill (62 Items)	100.0	NA	100.0	100.0

Motivational Analysis

The ARCS questionnaire assesses four motivational characteristics; attention, confidence, relevance, and satisfaction. Each characteristic is rated from one to five; not true to very true, respectively. The mean scores for each scale for the IMAT instruction are: Attention = 3.14, Confidence = 3.40, Relevance = 3.40, and Satisfaction = 3.33 (N = 53). These scores are not significantly different from the ARCS scores for an IMAT oceanography lesson taught at the AW "A" school which were collected in previous studies (Ellis & Parchman, 1994; Wetzel-Smith, S. K., Ellis, J. A., Reynolds, A. M., & Wulfeck W. H., 1995). Those scores were Attention = 3.43, Confidence = 3.35, Relevance = 3.76, and Satisfaction = 3.49. As reported in Wetzel-Smith, S. K., Ellis, J. A., Reynolds, A. M., & Wulfeck W. H. (1995), motivation scores in the ranges obtained in the present IMAT instruction lessons and the previous IMAT oceanography unit are significantly higher than scores obtained for traditional classroom instruction an introductory electricity course.

Conclusions

Several conclusions can be drawn from this evaluation. First, research on cognition and instruction and technological advances in scientific visualization can be integrated and applied in real world training to produce substantial gains in performance and student motivation. Second, the IMAT system has achieved its intended design goals by effectively teaching complex knowledge and cognitive skills. Third, the IMAT system emphasis on inclusion of required instructional components, especially practice opportunities, contributed significantly to the observed performance improvements. Overall, the results show that IMAT is a highly effective training system that offers a

viable solution for many of the training requirements and challenges faced by the four ASW communities (surface, subsurface, air, and surveillance) in the post Cold War world.

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